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ANALYSIS OF MEASUREMENTS OF WIDE-SECTOR INSTRUMENTS ABOARD THE "COSMOS-122" SATELLITE

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ANALYSIS OF MEASUREMENTS OF WIDE-SECTOR INSTRUMENTS ABOARD THE "COSMOS-122" SATELLITE

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ABSTRACT. The authors present a survey and qualitative comparison of the measurements of wide-sector instruments with the results of interpretation of television and infrared pictures taken by the "Cosmos-122" satellite as well as with the data of observations made by a network of ground meteorological stations.

The paper presents the curves of the distribution of the effective radiation temperature (T_r) and the shortwave radiation energy (Φ_{sw}) along orbits passing over Africa, the territory of the USSR and Pacific Ocean. The agreement of the paths of T_r and Φ_{sw} curves for orbits passing over Africa is examined. A comparison is made of the paths of T_r and Φ_{sw} curves with the intensity distribution of the cloud cover obtained on the basis of data from nephanalysis.

1 Table, 3 Figures, 6 Bibliographic entries.

The wide-sector instruments (WSI) of the "Cosmos-122" satellite are used to measure the radiation fluxes reflected and radiated by the Earth atmosphere system. It is theoretically possible to calculate the albedo and radiation balance for different regions of the globe on the basis of the measurements made by these instruments. However, the measurements made by the WSI are also of considerable interest from the standpoint of comparing them with information obtained by means of other types of instruments aboard the "Cosmos-122" and with ground observations of cloud cover. /42*

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* Numbers in the margin indicate the pagination in the original foreign text.

A similar comparison of the results of determining the effective temperature and albedo on the basis of data from measurements on outgoing radiation made aboard the "Tiros-III" satellite was made, for example, in [5, 6].

An analysis of the results of measurements made with the wide-angle detector of the "Tiros-III" satellite (a cone with an aperture angle of 35°) showed that they are in good agreement with existing theories of the reflectivity of various subjacent surfaces.

The entire disk of the Earth visible from the satellite is included in the field of vision of the WSI aboard the "Cosmos-122". However, since the angular sensitivity of the WSI changes according to the cosine law, the principal contribution to the WSI signal is made by the energy radiated from areas located close to the center of the Earth's disk. According to the calculations in [4], in the case of a uniform radiating surface 50% of the WSI signal is formed by energy from a radiant area about 500 km in diameter.

As a result of analysis of measurements made with the aid of instruments mounted aboard the "Cosmos-122", we plotted the curves of the distribution of the effective radiation temperature (T_r) and the shortwave radiation energy (Φ_{sw}) along orbits which are shown in Figures 1 and 2.

Figure 1 is striking in that it shows the agreement of the T_r and Φ_{sw} curves. The initial portions of the graphs correspond to the passage of the satellite over the surface of the Atlantic Ocean. In this case, the distribution curves for Φ_{sw} along the different orbits differ significantly from one another. This is explained by the fact that the reflectivity of the surface of the water is largely dependent on the angle of incidence of the solar rays. As the elevation of the Sun decreases, the albedo increases. On the whole, the albedos of water surfaces are less than those of land [2]. The distribution curves for T_r along different orbits show greater mutual agreement. This is explained by the fact that clear weather with few clouds predominates in these areas, and the temperature variations of the sea water are small.

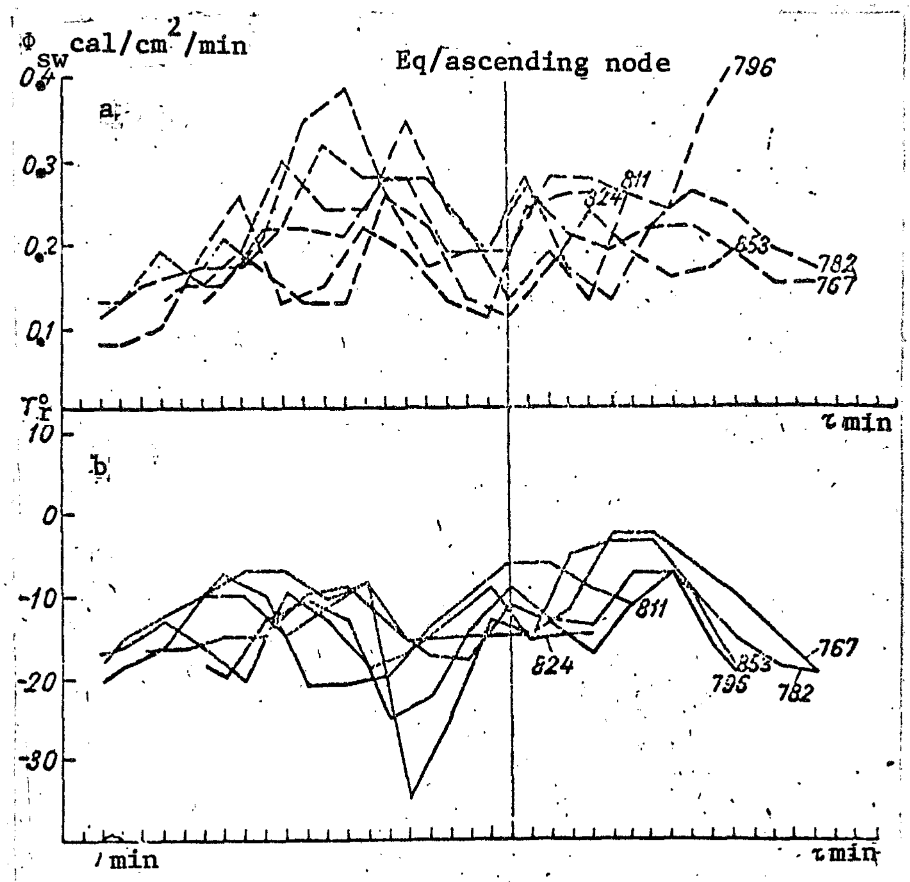

Figure 1. Graphs of Φ_{sw} (a) and T_r(b) for orbits passing over Africa. The numbers on the curves indicate the numbers of the orbits.

After the satellite crossed the Equator, the instruments recorded a minimum T_r and a maximum Φ_{sw}. Analysis of the weather charts for the periods closest to the time the satellite instruments were switched on showed that these extreme values of T_r and Φ_{sw} are related to persistent dense cumulus cloud covers in the basins of the Congo and Niger Rivers. We know that strato-cumulus and cumulo-nimbus clouds are characterized by the highest albedo values [3]. /43

The maximum T_r measured then corresponds to the passage of the satellite over the Sahara. There is no sharp drop in Φ_{sw} during this interval, since the reflectivity of the sandy surface is great. Such a curve pattern is in complete agreement with theories regarding the reflectivity of the ocean, cloud massifs and sandy surfaces.

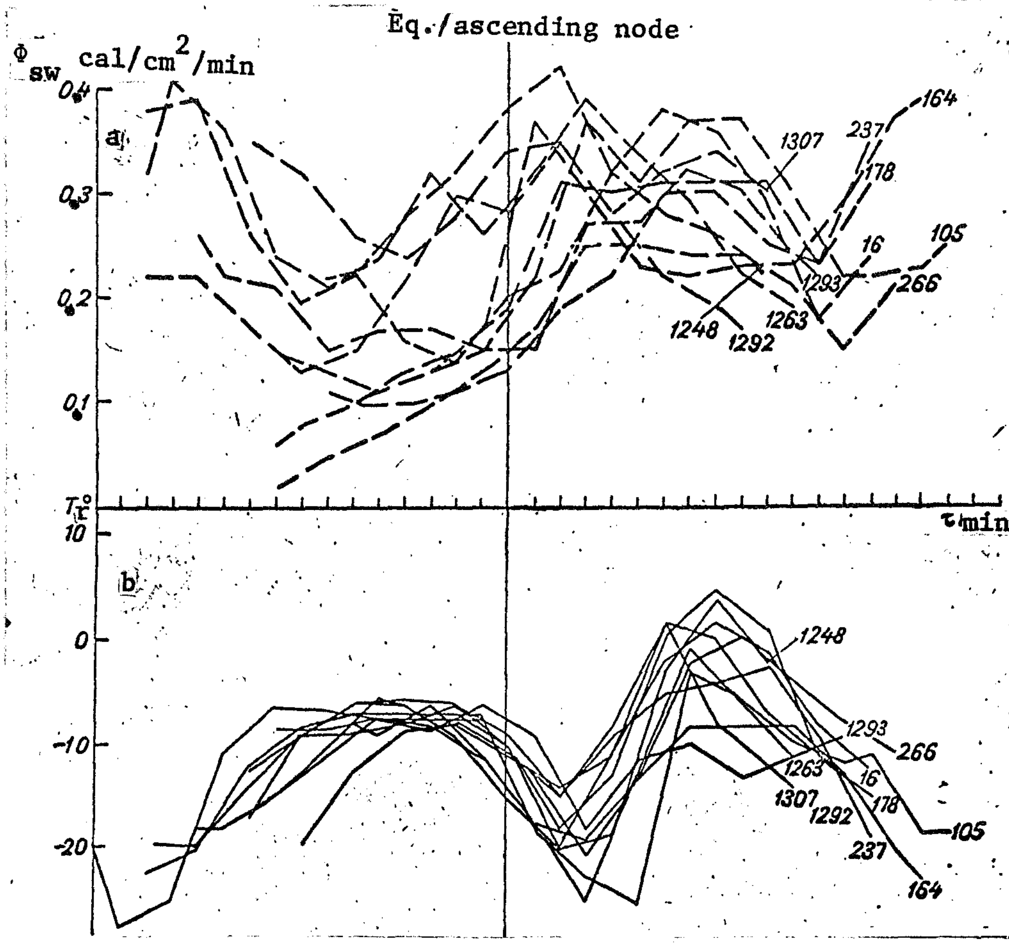

Figure 2. Graphs of Φ_{sw} (a) and T_r (b) for orbits passing over the territory of the USSR and the Pacific Ocean.

The extreme values of T_r and Φ_{sw} along orbits passing over the territories of the Soviet Union and the Pacific Ocean are related to the presence of cloud systems over these regions.

Thus, the analysis of the distribution curves for T_r and Φ_{sw} along the 811th orbit (19 August 1966, t_{on} = 0418 hours t_e = 0344 hours, λ_e = -40°36') (1)

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(1) The number of the orbit is followed by the date, the Moscow time when the WSI was switched on, and the Moscow time and altitude of the ascending mode of the orbit.

showed that the minimum T_r and the maximum Φ_{sw} at the 6^{th} minute following switching on the WSI correspond to the passage of the satellite over a cyclone whose center was located west of Taiwan. In this region, one can see cumulo-nimbus and cumulus clouds with considerable brightness and a low temperature at their upper limits. /44

On the 767^{th} orbit (16 August 1966, t_{on} = 0501 hours, t_e = 0434 hours, λ_e = -41°) the WSI measured a drop in T_r and an increase in Φ_{sw} as the satellite passed over the northern part of an anticyclone whose center was located southwest of Lake Baikal. Ground data from stations in the northern part of the anticyclone recorded fog.

These examples show that the WSI is sufficiently accurate in indicating cloud systems related to baric formations of synoptic scale. We know, however, that weather processes in middle latitudes show considerable change with time. This explains the observed scatter in the graphs of T_r and Φ_{sw} for these regions (Figure 2). In addition to the general outlines of the paths of the curves along orbits passing over Africa, some differences were observed whose explanation requires a more detailed analysis of the WSI data with the aid /45
of other forms of information.

The times the "Cosmos-122" instruments were switched on did not coincide with the synoptic periods. The time difference between the ground observations and the satellite ones amounted to several hours. In order to perform a common analysis of the data from satellite and ground observations, they must be related to a single period, which complicates the problem considerably. It is obviously more advantageous to compare the data of WSI measurements with television (TV) and infrared (IR) data. The detail in pictures of cloud cover taken by TV and IR cameras synchronously with the WSI measurements allowed comparison of the paths of the T_r and Φ_{sw} curves with the distribution of the amounts of cloud cover. The following work was undertaken to make this comparison.

On the basis of data from nephanalysis for each two-minute interval, we calculated the amount of dense cloud cover (cumulo-nimbus and strati-form) on a scale. This corresponds to determining the mean density of the cloud cover for squares measuring 1000 x 1000 km^2.

Table 1 shows the results of a calculation of the mean density of the cloud cover for measurements made by the WSI aboard "Cosmos-122" on the 1160th orbit (11 September 1966, t_{on} - 1749 hours, t_e = 1801 hours, λ_e = 10°20'), Φ_{sw} and T_r.

In the 14th minute following switching on of the WSI, the minimum T_r and maximum Φ_{sw} were observed; this was connected with the passage of the satellite over cumulo-nimbus clouds. This cloud massif showed up on the infrared photograph as white spots, since the temperature at the upper limits was low.

A maximum Φ_{sw} was also observed in the 8th minute. This increase in brightness was related to the presence of stratus clouds that appear in the pictures as a grey shroud and are detected by the shortwave instrument. The thermal instrument shows almost no reaction to it, since stratus clouds are low and have rather high temperatures.

TABLE I.

Time after switching on, minute	0	2	4	6	8	10	12	14	16	18	20
Cloudiness in scale divisions	2	2	1	1	0	0	1	4	4	1	1
T_r, °C	−9.5	−7.5	−5	−3.5	−3.5	−2.3	−6	−9.5	−5	1.2	1.2
Φ_{sw}, cal/cm^2/min	0.23	0.20	0.16	0.20	0.23	0.19	0.22	0.22	0.18	0.16	0.14

Support for the theory that a sandy surface has high brightness close to that of cumuli-form clouds is provided by the pattern of the Φ_{sw} curves for the 266th orbit (13 July 1966, t_{on} - 1123 hours, t_e = 1132 hours, λ_e = 07°04').

The 12th minute following switching on of the satellite instrument is marked by minimum T_r and maximum Φ_{sw} caused by the presence of strato-cumulus clouds. The maximum T_r follows six minutes later. At this time the satellite was passing over the Sahara, but Φ_{sw} did not decrease.

An analysis of the patterns of the curves for the 164th orbit (16 July 1966, t_{on} = 1424 hours, t_e = 1430 hours, λ_e = -25°04') showed that there is a sharp increase in brightness, up to 0.40 cal/cm^2/min, in the presence of cumulo-nimbus clouds. The radiation temperature at this time drops sharply, reaching -20° and less (Figure 3).

An examination of the curves characterizing the distribution of T_r and Φ_{sw} of all the orbits revealed the following ranges of extreme values of the measured parameters: from -35 to +9° for T_r and from 0.02 to 0.42 cal/cm^2/min for Φ_{sw}.

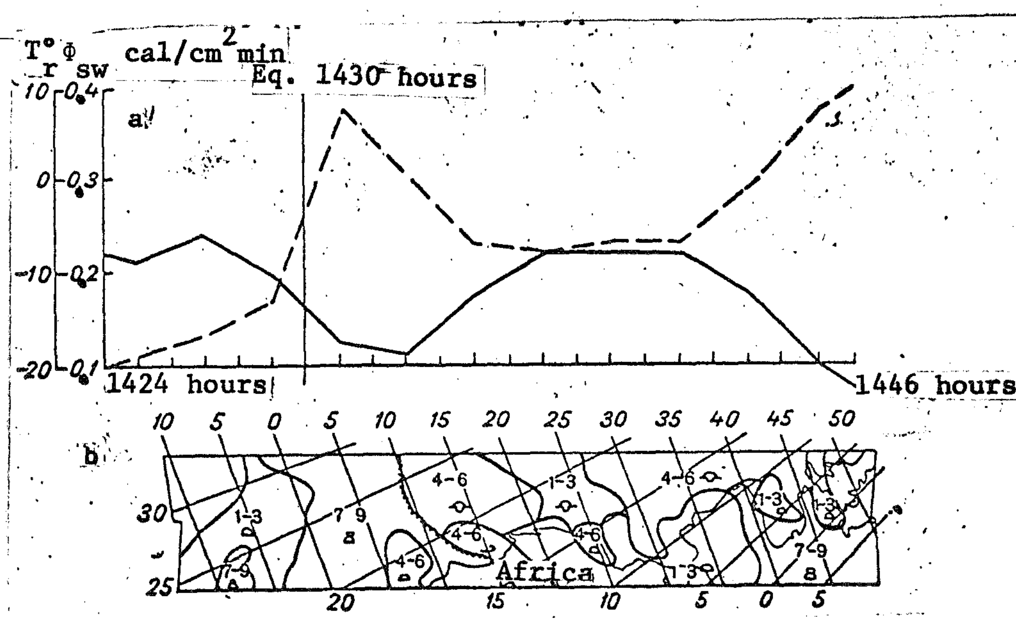

Figure 3. Graphs of T_r and Φ_{sw} (a) and Nephanalysis (b), obtained via television pictures for the 164th orbit.

Note that dense cumuliform clouds are usually associated with T_r less than -10°, as a rule. In the daytime, the sandy surface of the African desert has effective radiation temperatures on the order of 0, +5°.

An analysis of the WSI data showed that the radiation values measured by the WSI aboard the "Cosmos-122" are in good agreement with the radiation values obtained by other means and do not contradict our theories regarding the reflectivity of different objects.

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